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NORTH AMERICAN ORDOVICIAN OPHIUROIDEA THE GENUS *TAENIASTER* BILLINGS, 1858 (PROTASTERIDAE)

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By Frederick H. C. Hotchkiss[1]

Thirteen species of ophiuroids have been described from the Ordovician strata of North America. Of these, *Stenaster obtusus* (Forbes) (Stenasteridae), *Taeniaster spinosus* (Billings) (Protasteridae), and *Hallaster cylindricus* (Billings) (Lapworthuridae) are discussed at great length in Spencer's Monograph of the British Palaeozoic Asterozoa. The remaining species are essentially known only from their first appearance in the literature.

The type species of the genus *Taeniaster* Billings is *Palaeocoma spinosa* Billings of which there are three syntypes, two of which were figured by Billings (1858). Spencer (1934) did not select a lectotype but regarded the three specimens as "co-types" and proceeded to base the greater part of his general account of the genus on the unfigured syntype and some other material which he was able to 'identify' through this third specimen. The unfigured syntype presents an aboral view of a protasterid brittle-star while the figured syntypes present oral views.

I have had the extraordinary opportunity of studying the type material of all of the North American Ordovician species of Protasteridae as well as other material housed in the Smithsonian Institution and latex casts of type material of relevant species from Great Britain. I find that the syntype presenting an aboral view is neither conspecific nor congeneric

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with the two syntypes which present an oral aspect. It being no longer possible to regard the three syntypes as "co-types" as done by Spencer, the first-figured individual is selected as the lectotype. Thus the generic diagnosis given by Spencer and Wright (1966) in the Treatise on Invertebrate Paleontology for this form cannot stand. It is interesting to note that *T. spinosus* is an index fossil (Shimer and Shrock, 1944) and also appears in textbooks of paleontology (Moore, Lallicker, and Fischer, 1952).

The following generic diagnosis, specific description, and synonomy is new. The generic diagnoses of Spencer (1934) and Billings (1858) are readily available, the latter being quoted in full in Schuchert (1915).

Acknowledgments.—I wish to thank Dr. Porter M. Kier of the Smithsonian Institution for making this study possible by allowing use of the collections, facilities and equipment under his care. Some of the Smithsonian material had been set aside for study by Dr. H. B. Fell of the Harvard Museum of Comparative Zoology and I thank him for releasing that material for my study. Many people assisted this study by loaning material and providing latex casts of specimens; for these kindnesses I wish to thank Dr. Bernhard Kummel of the Harvard Museum of Comparative Zoology, Dr. Thomas E. Bolton of the Geological Survey of Canada, Mr. Clinton F. Kilfoyle of the New York State Museum, Dr. D. H. Collins of the Royal Ontario Museum, Dr. R. V. Melville of the Institute of Geological Sciences (London), Dr. Murray Mitchell of the Institute of Geological Sciences (Leeds), Dr. R. P. S. Jefferies and Mr. H. G. Owen of the British Museum (Natural History), Dr. Colin Forbes and Dr. R. B. Rickards of the Sedgwick Museum, and Dr. E. C. Wilson of the Los Angeles County Museum of Natural History. I am obliged to Dr. Howard R. Cramer of Emory University for critically reading the manuscript in its original form and to Dr. Karl M. Waage of Yale University for reading the final draft.

Abbreviations.—The following abbreviations are employed:

United States National Museum (Smithsonian Institution) .... USNM

New York State Museum .... NYSM
Harvard Museum of Comparative Zoology .... MCZ
Geological Survey of Canada .... GSC

SUBCLASS OPHIUROIDEA GRAY, 1840
ORDER OEGOPHIURIDA MATSUMOTO, 1915
SUBORDER LYSOPHIURINA GREGORY, 1896
Family Protasteridae S. A. Miller, 1889
Taeniaster Billings, 1858

Taeniaster Billings, 1858, Geol. Surv. Canada, Can. Org. Rem., dec. 3, p. 80 (in part). Type species *Palaeocoma spinosa* Billings by subsequent designation, Schuchert (1914, p. 42).—Chapman, 1861, Canadian Journ., n. ser., vol. 6, p. 517.—Wright, 1862, Mon. Brit. Foss. Echinod., Oolitic, vol. 2, pt. 1 (Palaeontogr. Soc. for 1861), pp. 24, 34.—Chapman, 1864, Expos. Min. Geol. Canada, p. 111.—Hall, 1868, 20th Rep. N. Y. State Cab. Nat. Hist., p. 300; also revised edition, 1868–1870, p. 338.—Zittel, 1879, Handb. Pal., vol. 1, p. 445.—Nicholson and Etheridge, 1880, Mon. Sil. Foss. Girvan Dist., p. 323.—Sturtz, 1886, Neues Jahrb. fur Min., Geol., Pal., vol. 2, p. 150.—Sturtz, 1886, Palaeontographica, vol. 32, pp. 78, 83.—Miller, 1889, N. Amer. Geol. Pal., p. 285 (in part).—Gregory, 1889, Geol. Mag., dec. 3, vol. 6, p. 26.—Gregory, 1897, Proc. Zool. Soc. London for 1896, p. 1035.—Gregory, 1900, Treat. Zool., vol. 3, Echinoderma, p. 251.—Cummings, 1908, 32d Ann. Rep. Dep. Geol. Nat. Res. Indiana, p. 715.—Schuchert, 1914, Fossilium Catalogus Animalia, pt. 3, p. 42.—Schuchert, 1915, USNM Bull. 88, p. 216 (in part).—Spencer, 1934, Mon. Brit. Pal. Asterozoa, pt. ix, p. 483 (in part).—Spencer and Wright, 1966, *in* Treatise on Invert. Paleont., pt. U, Echinodermata 3, p. U87 (in part).

Alepidaster Meek, 1872, Amer. Journ. Sci., ser. 3, vol. 4, p. 275.—Schuchert, 1915, USNM Bull. 88, p. 228 (in part).

Protaster Forbes.—Miller, 1889, N. Amer. Geol. Pal., p. 276 (in part).

Urosoma Spencer, 1930, Mon. Brit. Pal. Asterozoa, pt. viii, p. 433 (in part).

Drepanaster Whidborne.—Spencer, 1934, Mon. Brit. Pal. Asterozoa, pt. ix, p. 492 (in part).

(For further references see citations under species heading below).

Diagnosis: Interradial outline of disk generally straight or concave but may be convex; oral interradial areas of disk bear plates (of uncertain outline) and spines; aboral surface of disk invested with plates (of uncertain outline) and granules; margins of the disk perceptibly thickened in some material suggesting marginalia present; mouth angle plates short; first ambulacral short and stout; proximal ambulacrals only slightly excavated to accommodate the override of the first ambulacral; madreporite present. Arms taper uniformly; median suture between alternate ambulacrals straight, not sinuous. Ambulacral ossicles without

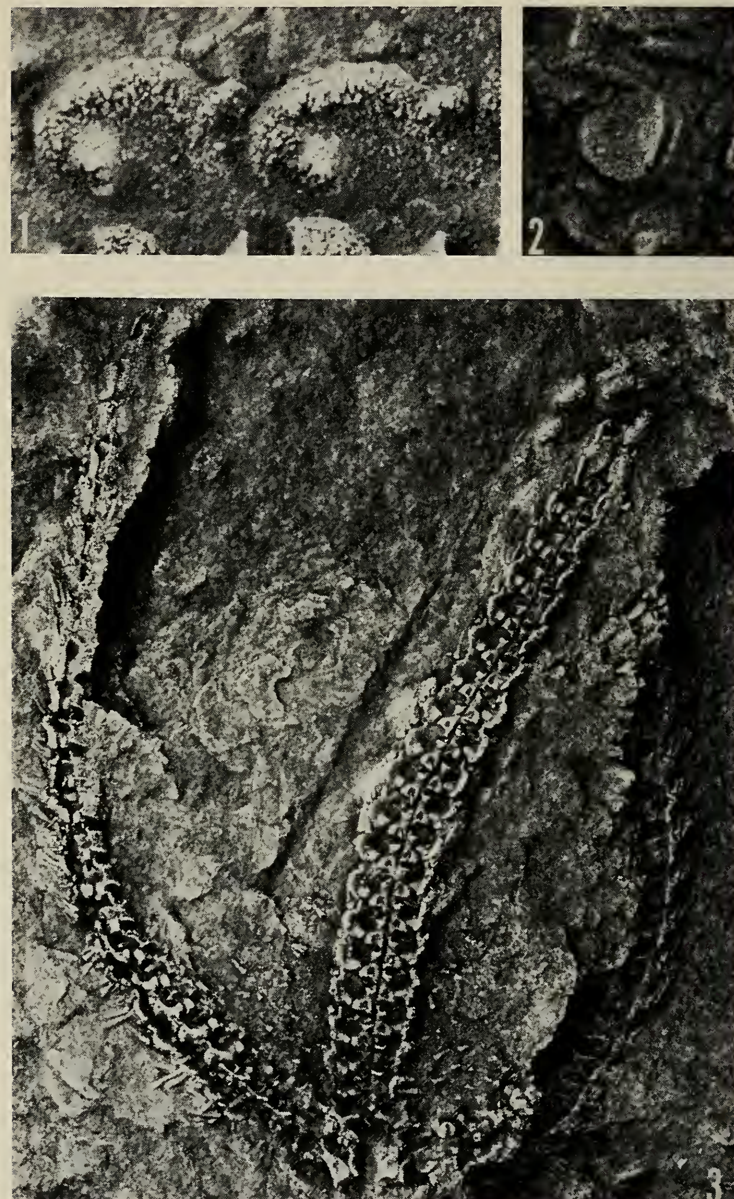

FIG. 1. *Taeniaster spinosus.* Lateral plates of an arm of USNM 92607 showing the characteristic ear-shape. ×30.

deep excavations for the insertion of dorsal longitudinal muscles; aboral outline of ambulacral ossicles therefore quadrate, not trapezoidal or triangular; oral surfaces of ambulacral ossicles ornamented at the ankle of the boot with a circular, subcircular or lemniscate depression; the waist of the boot is traversed by a groove leading from the median suture to the podial basin; the toe of the boot is variously pointed or blunt; proportions of the ambulacral boot vary along the arm; proximally the foot of the boot may be longer than the boot is tall. The laterals are generally ventral but there is great variation in the preserved attitude of the laterals relative to the ambulacral groove; from one view (fig. 1) the laterals are a diagnostic ear-shape; the laterals bear small proximal and distal fittings; both vertical and groove spines present.

Comparison with other genera: Taeniaster Billings closely resembles *Protaster* Forbes as described by Spencer (1934, p. 465) and further study may show these genera to have overlapping limits. A tentative difference is that *Protaster* as described by Spencer is not ornamented at the waist and ankle of the boot. The absence of deep excavations for the insertion of the dorsal longitudinal muscles in *Taeniaster* and *Protaster* distinguishes these genera from *Protasterina* Ulrich: type species by monotypy *Protasterina* (*Protaster* lapsus) *fimbriata* Ulrich (= *Protaster flexuosus* Miller and Dyer). *Drepanaster* Whidborne (type species by original designation *Protaster scabrosus* Whidborne) was diagnosed by Spencer (1934, p. 492) on the characters of *D. grayae* Spencer when, in fact, the genotype is vastly different; all that I am prepared to state at this time is that *D. grayae* is akin to *Protasterina.*

Remarks: I recognize but one species of *Taeniaster* in the material I have examined, the evidence for which is documented below under "Synonyms of *Taeniaster spinosus* (Billings)" and in the accompanying figures. In the description of the type species which follows, I have taken care to indicate those features which are noted in the lectotype and those which were noted from other specimens.

Range and distribution: Trentonian of Ontario and New York; Edenian of Kentucky; Maysvillian and Richmondian of Ohio; and the Richmondian of Indiana and Ontario.

Taeniaster spinosus (Billings)
Figures 1–9, 11

Palaeocoma spinosa Billings, 1857, Geol. Surv. Canada, Rep. Progr. for 1853–1856, p. 292.—Bolton, 1960, Cat. Type Invert. Foss. Geol. Surv., Canada, vol. 1, p. 91.

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FIG. 2. *T. spinosus.* The madreporite of an individual from USNM 92617. ×30.

FIG. 3. *T. spinosus.* A latex cast made from the holotype of *T. schohariae* Ruedemann. NYSM 7784. ×8½.


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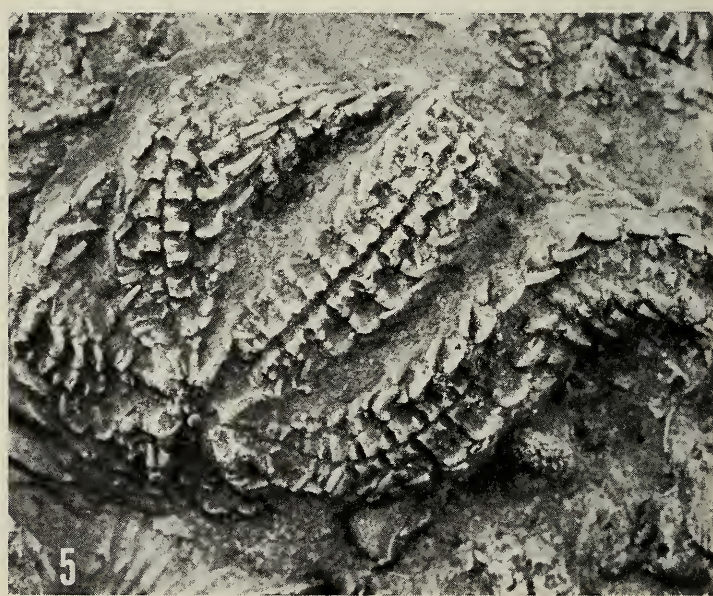
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Taeniaster spinosus (Billings).—Billings, 1858, Geol. Surv. Canada, dec. 3, p. 81, pl. x, figs. 3a–3d.—Wright, 1862, Mon. Brit. Foss. Echinod., Oolitic, vol. 2, pt. 1 (Palaeontogr. Soc. for 1861), p. 34.—Miller, 1889, N. Amer. Geol. Pal., p. 285, fig. 439.—Sturtz, 1893, Verh. naturh. Ver. preuss. Rheinl., etc., vol. 50, p. 20.—Parks, 1908, Trans. Canadian Inst., vol. 8, p. 363.—Ruedemann, 1912, Bull. N. Y. State Mus., No. 162, p. 89.—Schuchert, 1914, Fossilium Catalogus Animalia, pt. 3, p. 42.—Schuchert, 1915, USNM Bull. 88, p. 219, text fig. 17, pl. 36, fig. 1.—Bassler, 1915, USNM Bull. 92, vol. 2, p. 1256.—Spencer, 1934, Mon. Brit. Pal. Asterozoa, pt. ix, p. 488, text figs. 291c, 292, 293, 315–320, pl. xxxi, fig. 9 (in part).—Willard, 1937, Journ. Paleont., vol. 11, no. 7, p. 622.—Shimer and Shrock, 1944, Index Foss. N. Amer., p. 213.

Protaster? granuliferus Meek, 1872, Amer. Journ. Sci., ser. 3, vol. 4, p. 274 (*Alepidaster* at end of description).—Meek, 1873, Geol. Surv. Ohio, Paleont., vol. 1, p. 68, pl. 3 bis, figs. 8a, 8b (*Alepidaster* at end of description).—Lesley, 1889, Geol. Surv. Pennsylvania Rep., p. 4.—Miller, 1889, N. Amer. Geol. Pal., p. 276.—James, 1896, Journ. Cincinnati Soc. Nat. Hist., vol. 18, p. 138.—Parks, 1908, Trans. Canadian Inst., vol. 8, p. 368.

Taeniaster elegans Miller, 1882, Journ. Cincinnati Soc. Nat. Hist., vol. 5, p. 41, pl. i, figs. 6–6c.—Miller, 1889, N. Amer. Geol. Pal., p. 285.—James, 1896, Journ. Cincinnati Soc. Nat. Hist., vol. 18, p. 139.—Parks, 1908, Trans. Canadian Inst., vol. 8, p. 368.—Ruedemann, 1912, Bull. N. Y. State Mus., No. 162, p. 89.—Schuchert, 1914, Fossilium Catalogus Animalia, pt. 3, p. 42.—Foerste, 1914, Bull. Sci. Lab. Denison Univ., vol. 17, p. 328.—Schuchert, 1915, USNM Bull. 88, p. 221.—Bassler, 1915, USNM Bull. 92, vol. 2, p. 1255.—Spencer, 1934, Mon. Brit. Pal. Asterozoa, pt. ix, p. 491.—Willard, 1937, Journ. Paleont., vol. 11, no. 7, p. 622.

Protaster miamiensis Miller, 1882, Journ. Cincinnati Soc. Nat. Hist., vol. 5, p. 116, pl. 5, figs. 6, 6a, 6b.—Miller, 1889, N. Amer. Geol. Pal., p. 276.—James, 1896, Journ. Cincinnati Soc. Nat. Hist., vol. 18, p. 138.—Parks, 1908, Trans. Canadian Inst., vol. 8, p. 368.—Spencer, 1934, Mon. Brit. Pal. Asterozoa, pt. ix, p. 437.

Taeniaster granuliferus (Meek).—Cumings, 1908, 32d Ann. Rep. Dep. Geol. Nat. Res., Indiana, p. 733, pl. 3, fig. 7.

Taeniaster schohariae Ruedemann, 1912, Bull. N. Y. State Mus., No. 162, p. 88, pl. 3, fig. 1.—Schuchert, 1914, Fossilium Catalogus Animalia, pt. 3, p. 42.—Schuchert, 1915, USNM Bull. 88, p. 220.—Bassler, 1915,

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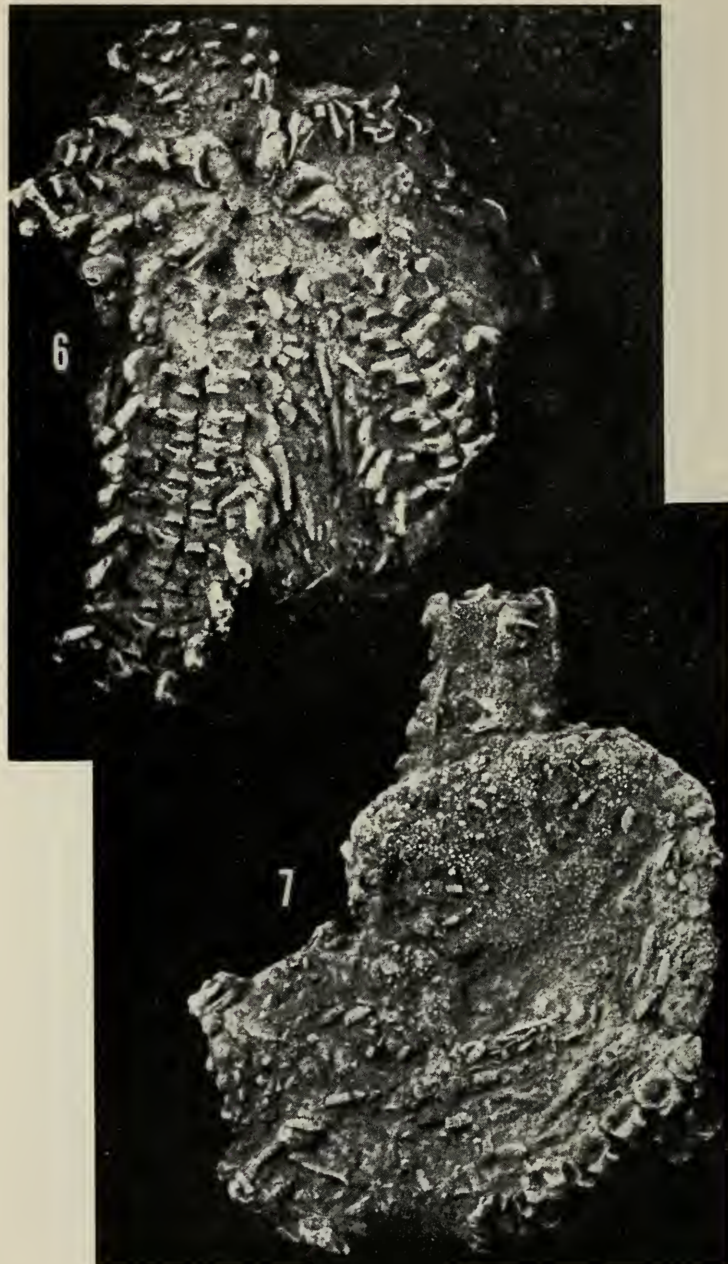
FIG. 4. *T. spinosus.* A view of the aboral surface as seen in USNM 92604. ×4½.

FIG. 5. *T. spinosus.* One of the syntypes of *T. elegans* Miller. USNM 40878. ×7.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USNM Bull. 92, vol. 2, p. 1255.—Willard, 1937, Journ. Paleont., vol. 11, no. 7, p. 622.

Alepidaster granuliferus (Meek).—Schuchert, 1914, Fossilium Catalogus Animalia, pt. 3, p. 11.—Schuchert, 1915, USNM Bull. 88, p. 230, fig. 26.—Bassler, 1915, USNM Bull. 92, vol. 1, p. 25.—Spencer, 1934, Mon. Brit. Pal. Asterozoa, pt. ix, p. 492.

Alepidaster miamiensis (Miller).—Schuchert, 1914, Fossilium Catalogus Animalia, pt. 3, p. 11.—Schuchert, 1915, USNM Bull. 88, p. 233.—Bassler, 1915, USNM Bull. 92, vol. 1, p. 25.

Taeniaster meafordensis Foerste, 1914, Bull. Sci. Lab. Denison Univ., vol. 17, p. 326, pl. 4, figs. 5–7.—Schuchert, 1915, USNM Bull. 88, p. 221.—Bassler, 1915, USNM Bull. 92, vol. 2, p. 1255.—Foerste, 1924, Geol. Surv., Canada, Mem. 138, p. 104, pl. 8, figs. 1–4.—Willard, 1937, Journ. Paleont., vol. 11, no. 7, p. 622.—Bolton, 1960, Cat. Type Invert. Foss. Geol. Surv., Canada, vol. 1, p. 93.

Taeniaster miamiensis (Miller).—Foerste, 1914, Bull. Sci. Lab. Denison Univ., vol. 17, p. 328.—Willard, 1937, Journ. Paleont., vol. 11, no. 7, p. 622.

Protaster (*Taeniaster*) *spinosus* (Billings).—Spencer, 1922, Mon. Brit. Pal. Asterozoa, pt. v, p. 201, text fig. 140.

Urosoma hirudo (Forbes).—Spencer, 1930 and 1934, Mon. Brit. Pal. Asterozoa, pt. vii, p. 434, text figs 278–280, pl. xxvii, figs. 3, 4, 5; pt. ix, p. 437, text figs. 281, 282, pl. xxix, figs. 1, 2, 3 (in part).

Drepanaster schohariae (Ruedemann).—Spencer, 1934 and 1940, Mon. Brit. Pal. Asterozoa, pt. ix, p. 493; pt. x, p. 500.

Diagnosis: As for the genus—monotypic.

Material: USNM 40878 (syntypes of *T. elegans*), USNM 40886 (syntypes of *Protaster miamiensis*), USNM 87166 (syntypes of *T. meafordensis*), USNM 92604, USNM 92607, USNM 92617, USNM 92627, USNM 92639, USNM 161520, NYSM 7784 (holotype of *T. schohariae*), MCZ 470 (holotype of *Protaster*? *granuliferus*; ex MCZ 21), GSC 1404 (herein selected as lectotype of *Palaeocoma spinosa*), GSC 1404a (paralectotype of *Palaeocoma spinosa*—herein referred to *Protasterina*), GSC 1404b (paralectotype of *Palaeocoma spinosa*), GSC 8580, a, b, c (syntypes of *T. meafordensis*).

Disk: Very few details of the disk have been discerned. The interradial margin of the disk is straight, concave, or, rarely, convex and in some individuals is slightly thickened (fig. 4) suggesting marginalia though the thickening could also be from the folding of the disk at this locus. USNM 40878 is notable for the seeming absence in oral view of

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FIG. 6. *T. spinosus*. The oral surface of the holotype of *Protaster*? *granuliferus* Meek. MCZ 470. ×9.

FIG. 7. *T. spinosus*. The aboral surface of the holotype of *Protaster*? *granuliferus* Meek. MCZ 470. ×9.

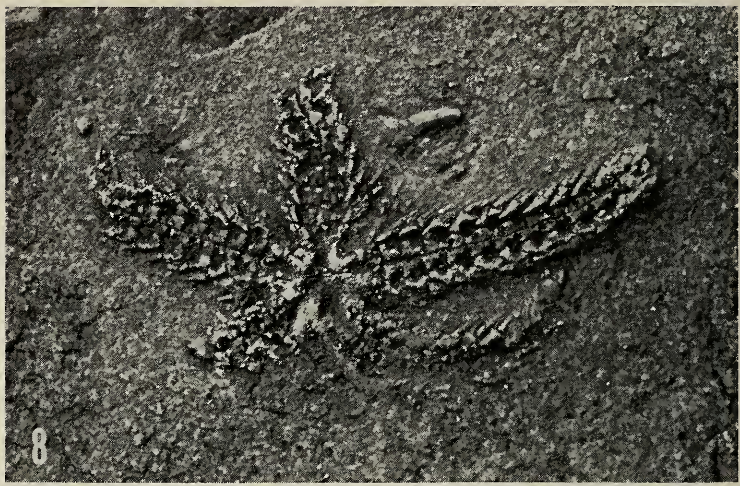

FIG. 8. *T. spinosus*. The lectotype. GSC 1404. ×7½.
FIG. 9. *T. spinosus*. A paralectotype. GSC 1404b. ×7½.

the disk (fig. 5) although very slight traces are to be found in the interradii of some individuals.

MCZ 470 (fig. 7), GSC 1404b (fig. 9), GSC 8580c, and USNM 92604 (fig. 4) present aboral views of the disk. The disk plates are highly ankylosed and overlain by fine granules.

The oral interradial aspect of the disk is invested with plates which are so ankylosed that it is impossible to determine their shape. Spines are found in the oral interradial areas of many individuals including the lectotype, however, some of these spines are dislodged vertical or groove spines. NYSM 7784 clearly demonstrates small disk spines unconfused with groove or vertical spines (fig. 3).

Mouth frame: The oral aspect of the mouth frame is well illustrated in the lectotype (fig. 8), MCZ 470 (fig. 6), USNM 40878 (fig. 5), NYSM 7784 (fig. 3), and GSC 8580 (fig. 11). The mouth angle plates form short V's; the oral wedge (*i. e.* the area included by the radial bow of the ambulacrals and virtually subtended by the proximal end of the syngnaths) is small as the first ambulacral is also short. The apophyses of the mouth angle plates seat the vertically elongated, oval torus seen clearly in MCZ 470 (fig. 6). No teeth have been observed. The cup for the first tube foot is not visible but probably lies within the radial bow apical to the proximal ridge bordering the cup for the second tube foot (Spencer: 1930, p. 403). The cup for the second tube foot is most clearly visible in NYSM 7784 (fig. 3) and is seen to be differentiated so as to assist in bringing food to the mouth.

The aboral aspect of the mouth frame is visible in USNM 92604 (fig. 4). The short, stout first ambulacral and the short, thin mouth angle plates are seen to be ornamented with a groove for the water-ring; the groove for the nerve-ring and the pseudohemal vessels was not separately identified. The proximal ambulacrals are only slightly excavated to accommodate the overriding action of the first ambulacral during opening of the mouth aperture.

Madreporite: The madreporite was found in MCZ 470 (fig. 6), GSC 9580 (fig. 11), USNM 92617 (fig. 2) and NYSM 7784 (fig. 3). It approximates a disk with a simple channel traversing approximately two-thirds of the rim, except in NYSM 7784 (fig. 3) where the madreporite is swollen, appearing subspherical with the channel showing as a wide crease. It is located to the right of the second lateral plate on the oral surface of the disk.

Arms: The arms taper uniformly. In aboral view usually only the double row of ambulacral plates is visible; USNM 92604 (fig. 4) is an exception with the laterals spread outward from the rays. The median suture separating the double row of ambulacral plates is straight. In oral view the lateral plates margin the ambulacral groove which is roofed over by the biserially arranged ambulacrals. (N. B. that the aboral aspect of the arms is not visible in the lectotype and is scarcely evident in paralectotype GSC 1404b.)

FIG. 10. ? *Protasterina* sp. Technically, this specimen is a paralecto-type of *T. spinosus*. The deep excavations for the insertion of the dorsal

Ambulacrals: The proximal ambulacral boots have short, stout boot-legs with the foot of the boot longer than the boot is tall; beyond the first few ambulacrals the foot of the boot shortens and the boot is taller and thinner.

The ambulacral boot is ornamented at the ankle with a depression to which Spencer (1925, p. 254) ascribes the function of seating tissues to support the radial nerve and pseudohemal canal; on the first few ambulacrals, however, it extends out into the foot; distally it becomes oval as the ambulacrals narrow.

The waist of the boot is traversed by a groove leading from the median suture to the podial basin. Spencer (1925, p. 254) deduced that this groove accommodated branches from the radial nerve and pseudohemal canal to the tube foot. The groove is transverse to the boot-leg except in NYSM 7784 (fig. 3) where it traverses the waist obliquely.

Several of the halves of vertebrae of the individual from USNM 40878 shown in figure 5 show the ventral muscle field excavating the sole of the ambulacral boot for the insertion of one end of the ventral longitudinal muscle; there is a corresponding excavation on the top of the ambulacral boot-leg. The ridge separating the dorsal and ventral muscle-fields and participating in the articulation between serial halves of vertebrae is visible in one of the arms of NYSM 7784 (fig. 3) where the laterals have fallen away and permit a lateral view of the ambulacrals.

Viewed aborally the proximal ambulacrals are approximately square in outline; the distal ambulacrals are rectangular in outline with the longer edge being along the axis of the arm. In MCZ 470 and USNM 92604 the ambulacrals bear a saddle-shaped depression extending to the lateral edge of the plate; in other material (notably USNM 92617, USNM 40878 and NYSM 7784) this saddle-shaped depression is not evident. The spacing between the ambulacrals for the dorsal longitudinal muscles is more evident in USNM 92604 (fig. 4) and NYSM 7784 (fig. 3) that in other material examined.

MCZ 470 (fig. 7) and USNM 92617 provide views of the ambulacral surface facing the median suture. It is found to be excavated to form a sinuous hollow canal within the arm for the radial water vessel.

Laterals: The laterals are a characteristic ear shape when viewed as shown in figure 1. From other viewpoints they are not especially distinctive except that the proximal and distal fittings are small.

Vertical spines are at least three in number, about as long as an arm segment, taper evenly to a point, and while essentially straight may curve slightly. The groove spines are also at least three in number, about

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longitudinal muscles are similar to those found in *Protasterina*. GSC 1404a. ×5.

Fig. 11. *T. spinosus*. The oral surface of one of the syntypes of *T. meafordensis*. GSC 8580. ×5.

as long as an arm segment, wider at the blunt tip than at the base, and essentially straight.

Measurements: Measurements were obtained using calipers. Irregularities in preservation and geometry of the individuals created some subjectivity in measurement; however, the data serves to illustrate the size range of the material. While the r/R ratio is generally smaller in specimens of larger disk size, USNM 92639 and USNM 92604 have disproportionately high ratios indicating great variation in this regard.

		r	*R*
GSC	1404	1.8 mm	6.3 mm
GSC	1404b	–	10.6 mm
GSC	8580	3.6 mm	13.5 mm
USNM	40878	–	16.8 mm
USNM	40886	4.7 mm	24.8 mm
USNM	92604	5.4 mm	13.9 mm
USNM	92617	3.1 mm	9.0 mm
USNM	92639	3.8 mm	11.7 mm
USNM	161520	3.9 mm	–
NYSM	7784	3.7 mm	15.5 mm
MCZ	470	4.7 mm	–

Formation and locality: Unless otherwise indicated, the data are taken from the label accompanying the specimen(s) and/or the data accompanying original description of the specimen(s).

Billings' material (GSC 1404 and GSC 1404b) is from the "Trenton," Middle Ordovician, Montmorency Falls, Quebec (Bolton, 1960). NYSM 7784, the holotype of *T. schohariae*, is from the Schenectady Formation near Schoharie Junction, New York.

USNM 92617 bears the labels "Eden (100′)" and "Covington, Kentucky" which suggest the locality given by Schuchert (1915) for the syntypes of *Protasterina fimbriata*, namely: "the lower Eden at about 100 feet above low-water mark in the Ohio River at Covington, Kentucky." USNM 161520 bears the label Eden, Covington, Kentucky. These specimens are regarded as from the Eden Group without specification of formation.

The labels of USNM 40878, USNM 92639 and USNM 92604 show these specimens to be from the Waynesville Formation of the Richmond Group; the first two are from Waynesville, Ohio and the third is from Oregonia, Ohio. Also from Oregonia, Ohio is USNM 92627 which is from the Richmond Group without specification of formation. The syntypes of *Protaster miamiensis* (USNM 40886) collected near Waynesville, Ohio are cited in Bassler (1915) as coming from possibly the Waynesville Formation or the Liberty Formation of the Richmond Group. The holotype of *Protaster*? *granuliferus* (MCZ 470) collected at Moore's Hill, Indiana is cited in Bassler (1915) as coming from the Richmond Group without specification of formation.

USNM 92607 bears a label indicating the material was collected from the Corryville Member of the McMillan Formation of the Maysville Group at Cincinnati, Ohio.

GSC 8580, a, b, c and USNM 87166, syntypes of *T. meafordensis*, were collected about 220 feet above Lake Huron, on Workman's Creek, three miles southeast of Meaford, Ontario, in the Meaford Formation (Upper Ordovician).

Location of type specimen: The lectotype of *Taeniaster spinosus* (Billings) (= *Palaeocoma spinosa* Billings) is No. 1404 in the collections of the Geological Survey of Canada.

Remarks: Specimens GSC 1404 and GSC 1404b were figured by Billings (1858, pl. x, figs. 3a–3d). Spencer (1934, p. 488) was the first to mention the third specimen (GSC 1404a) stating that "The third, which is not in such a good state of preservation, is important, because it is the only one of them which shows the apical surface of the arm. I am regarding the three as co-types of the species." Through GSC 1404a, Spencer was able to identify other Canadian material held in the British Museum (Natural History) and also the species *Protaster whiteavesianus* Parks with *Taeniaster spinosus*. If Spencer had seen the material that I have had access to, I feel sure that he too would have concluded that GSC 1404a (fig. 10) is not a specimen of *T. spinosus*. GSC 1404a, *Protasterina flexuosa* (Miller and Dyer), *Protaster whiteavesianus, T. maximus* Willard, *Drepanaster grayae*, and the material of "*T. spinosus*" described by Cramer (1957, p. 906) all possess ambulacrals which are deeply excavated for the insertion of the dorsal longitudinal muscles. Pending further study of these forms, they are all tentatively placed in the genus *Protasterina*.

I have examined MCZ 458 (formerly MCZ 28, MCZ 29, and MCZ 30) as Schuchert (1915, p. 230) thought this material represented a new species of *Alepidaster*. This examination has shown that the mouth frame and ambulacrals of this material are developed much as in *Protasterina*.

Synonyms of *Taeniaster spinosus* (Billings)

Protaster? *granuliferus* (*Alepidaster* at end of description) Meek, 1872 Amer. Journ. Sci., ser 3, vol. 4, p. 274.

Remarks: This species is based on a single specimen, MCZ 470, which provides excellent detail as may be seen from figures 6 and 7. Every feature found in the lectotype and paralectotype of *T. spinosus* is evident. It is one of the larger specimens available for study and bears a particularly well preserved madreporite.

Taeniaster elegans Miller, 1882, Journ. Cincinnati Soc. Nat., vol. 5 p. 41, pl. 1, figs. 6, 6a–6c.

Remarks: As stated by Miller, this species was founded upon more than thirty specimens occurring on a single slab (USNM 40878), but showing only the ventral side, with the exception of the ends of some of the rays. An individual is illustrated in figure 5. The disk is scarcely evident in the interradii. Miller correctly noted that only two rows of plates form the dorsal side of the ray, the laterals being ventral. As with other material that I am uniting with *T. spinosus*, the ambulacral boots are clearly ornamented at the ankle with a depression and at the waist of the boot by a groove leading from the median suture to the podial basin. While groove spines are largely missing in this material, vertical spines are exceedingly well preserved.

Protaster miamiensis Miller, 1882, Journ. Cincinnati Soc. Nat. Hist., vol. 5, p. 116, pl. 5, figs. 6, 6a, 6b.

Remarks: I have examined the five syntypes of this species (USNM 40886). Although much obscured by matrix, the proximal ambulacral ossicles are seen to have at the waist of the boot the groove leading from the median suture to the podial basin. The toes of the proximal boots are pointed as in the lectotype of *T. spinosus* and traces of a depression on the ankle of the boot further confirms the identity of this species with Billings'. Groove spines are particularly noticeable in this material, probably due to its lack of weathering. The specimens present the oral aspect.

Taeniaster schohariae Ruedemann, 1912, Bull. N. Y. State Mus., No. 162, p. 88, pl. 3, fig. 1.

Remarks: Ruedemann's description and figure contain many errors and do not adequately describe the single individual upon which the species is based (NYSM 7784). It is not surprising, therefore, that Spencer erroneously referred this species to *Drepanaster*. I provide here a photograph (fig. 3) of a cast made from the holotype which shows what a fine specimen it is. It is readily observed that the laterals are ear-shaped, with small proximal and distal fittings; that both groove and vertical spines are present; that the mouth angle plates are short and stout; that a madreporite is present; that the ambulacrals are not deeply excavated for the insertion of the dorsal longitudinal muscles; that the ambulacral boot is ornamented at the ankle with a subcircular depression and at the waist with a groove leading from the median suture to the podial basin; that the median suture is straight, not sinuous; and that small spines are scattered in the ventral interradial areas of the disk. The similarity of posture between NYSM 7784 and GSC 1404b is also worthy of note.

Taeniaster meafordensis Foerste, 1914, Bull. Sci. Lab. Denison Univ., vol. 17, p. 326, pl. 4, figs. 5–7.

Remarks: GSC 8580, a, b, c and USNM 87166 are the syntypes of this species. The individual from GSC 8580, illustrated in figure 11, shows that the mouth angle plates are short and stout; that a madreporite is present; that the ambulacral boot is ornamented at the ankle with subcircular depression and at the waist with a groove leading from the median suture to the podial basin; and that the median suture is straight, not sinuous. Other individuals, particularly from GSC 8580c, show that the ambulacrals are not deeply excavated for the insertion of the dorsal longitudinal muscles.

Literature Cited

Bassler, R. S. 1915. Bibliographic Index of American Ordovician and Silurian Fossils, U.S. Nat. Mus. Bull. 92, 2 vols., 1,521 p.

Billings, E. 1858. On the Asteriadae of the Lower Silurian Rocks of Canada. Geol. Surv. Canada, Canadian Organic Remains, dec. 3, pp. 75–85.

Bolton, T. E. 1960. Catalogue of Type Invertebrate Fossils of the Geological Survey of Canada, Vol. 1. Geol. Surv. Can., 215 p.

Cramer, H. R. 1957. Ordovician Starfish from the Martinsburg Shale, Swatara Gap, Pennsylvania. Journ. Paleont., vol. 31, no. 5, pp. 903–907, pl. 108, 1 text fig.

Moore, R. C., C. G. Lalicker, and A. G. Fischer. 1952. Invertebrate Fossils. McGraw-Hill, 766p., text figs.

Schuchert, C. 1915. Revision of Paleozoic Stelleroidea with Special Reference to North American Asteroidea. U.S. Nat. Mus. Bull. 88, 311 p., 38 pls., text figs.

Shimer, H. W., and R. R. Shrock. 1944. Index Fossils of North America. Technology Press (M. I. T.), 837 p., 303 pls.

Spencer, W. K. 1925. A Monograph of the British Palaeozoic Asterozoa, pt. vi, Palaeontogr. Soc. for 1922, pp. 237–324, pls. xviii–xxii, text figs.

————. 1930. A Monograph of the British Palaeozoic Asterozoa, pt. viii, Palaeontogr. Soc. for 1928, pp. 389–436, pls. xxv–xxviii, text figs.

————. 1934. A Monograph of the British Palaeozoic Asterozoa, pt. ix, Palaeontogr. Soc. for 1933, pp. 437–494, pls. xxix–xxxii, text figs.

————, and C. W. Wright. 1966. Asterozoans. *In* Treatise on Invertebrate Paleontology, pt. U., Echinodermata 3, vol. 1, pp. U4–U107, figs. 1–89.

Willard, B. 1937. *Taeniaster* in Pennsylvania. Journ. Paleont., vol. 11, no. 7, pp. 620–623, 1 text fig.